AOSN MURI: REAL-TIME OCEANOGRAPHY WITH AUTONOMOUS OCEAN SAMPLING NETWORKS: A CENTER FOR EXCELLENCE

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LONG-TERM GOALS

Long-term goals of this project are to create and demonstrate a reactive survey system, capable of long-term unattended deployments in harsh environments. We refer to such a system as an Autonomous Ocean Sampling Network (AOSN). The work described below is the product of a collaboration of research groups at the Massachusetts Institute of Technology, Woods Hole Oceanographic Institution, Scripps Institution of Oceanography, University of Washington, and Northeastern University.

OBJECTIVES

1) To create small, high performance mobile platforms capable of deployments lasting for several months. Both propeller-driven, fast survey vehicles, and buoyancy-driven glider vehicles are being pursued.

2) To create an infrastructure that supports controlling, recovering data from, and managing the energy of, remotely deployed mobile platforms. Elements include moorings, docking stations, acoustic communications, two-way satellite communications, and the Internet.

3) To demonstrate these capabilities in science-driven field experiments.

Odyssey IIb deployment from the Cape Hatteras, May 1997, Cape Cod Bay.

4) To develop adaptive sampling strategies to most efficiently meet deployment objectives.

APPROACH

The effort is coupled with a series of science-driven experiments, each chosen to focus instrumentation development and to convincingly demonstrate new capabilities. The first deployment, June-July 1996, during the Ocean Frontal Dynamics Primer Initiative in Haro Strait, focused on coordinated platform operations, adaptive sampling, and communications. The second deployment, January-April 1998, in support of the Labrador Sea Accelerated Research Initiative (ARI), is designed to demonstrate long-term deployment and remotely controlled operations. The final phase of the effort will integrate the re-

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sulting operational capabilities with modeling systems in an extended deployment experiment in coastal waters.

Phase 1 Activities: Platform and Operations Development
The two classes of survey platforms under development in this initiative are the small, propeller-driven vehicles and buoyancy-driven gliders. The first systems, autonomous underwater vehicles (AUVs), are capable of moving at several knots for part of a day, while the second systems, gliders, operate for several months at much lower speeds. The gliders developed under this initiative are entirely new systems. In contrast, the propeller-driven vehicles (Odyssey IIb AUVs) were developed under prior ONR support and are being augmented in this activity.

AUV efforts have focused on integration of oceanographic sensors and development of new operational techniques. Acoustic communications is a key facilitating technology for AUV operations. We are developing an acoustic modem designed for small AUVs. Operations in Haro Strait highlighted the advantages gained from an acoustic link for both routine operations and adaptive survey strategies.

Phase 2 Activities: Unattended Deployment
An extended deployment capability for small, high performance AUVs is being created by developing a docking capability which allows vehicles to use moorings as fuel stations and communication relays. This requires the high-efficiency power transfer and high bandwidth data link between a dock and a connected vehicle developed by Electronic Design Consultants. By providing satellite communication capabilities to the dock via a surface buoy, the ability to reprogram and extract data from docked vehicles is realized. To develop docking and acoustic communication, MIT is collaborating with the Woods Hole Oceanographic Institution. Satellite communications and mooring systems are also being developed at the Woods Hole Oceanographic Institution.

The first test of long term AUV deployment will occur in the context of the Labrador Sea Deep Oceanic Convection experiment early in 1998. An AUV-mooring system will be deployed and used to respond to convection events. The mooring will include a surface buoy with satellite communications and the dock will have sufficient power for 72 hours of vehicle missions.

Phase 3 Activities: Coupled Observation/Modeling System
Following the Labrador Sea experiment, activity will shift to creating an integrated observation/modeling system. An extended field deployment in a logistically convenient location is planned. The New England shelf, with the large variety of oceanographic processes, is a promising venue.

WORK COMPLETED

The MURI is developing two gliders. The University of Washington is conducting shallow water tests on a prototype glider. A WHOI-Scripps collaboration is also developing a glider, although the prototype system is not as far advanced. Both systems are battery powered, and can run for several months. Also, both systems are designed to incorporate satellite communications for data recovery and controlling the vehicle’s trajectory. The University of Washington team demonstrated their vehicle with a cellular phone connection, while the WHOI-Scripps vehicle will incorporate a link to the ORBCOM satellite system.

During the summer of 1996, AUV operations supported the Frontal Mixing Primer involving extensive field work in Haro Strait. Accomplishments include: multiple AUV surveys under acoustic control from the surface, moving source tomography using an AUV as the moving source (with H. Schmidt, MIT

acoustic group), and coordinated AUV-drifter operations (in collaboration with D. Farmer at the Institute for Oceanographic Science). Over 80 vehicle missions were carried out in currents sometimes exceeding 3 knots without vehicle loss or failure.

We maintained a brisk pace of deployments in 1997. Odyssey operations in New Zealand during February represented ONR's contribution to a cooperative effort, with National Geographic and the Smithsonian Institute, searching for the giant squid. In May and October, the Odyssey vehicles were employed for docking tests. Also in October, a side-scan sonar equipped Odyssey was used to demonstrate bathymetric mapping capabilities to the Naval Oceanographic Office (NAVOCEANO).

Field experiments during the MURI have demonstrated a number of homing and docking systems. Electronic Design Consultants brought the vehicle into a cone shaped dock with an electromagnetic homing system. The Naval Research and Development Center demonstrated optical homing, also into a cone-shaped dock. WHOI employed acoustic homing, using an ultrashort baseline system on the AUV, to home on a vertical pole. Tests in May and October 1997, using the WHOI approach, demonstrated docking, in situ power transfer, and deep-water dock deployment. Particularly important is the successful integration of the dock onto a deep-water mooring, complete with two-way satellite communications. The integrated system was successfully deployed and recovered in October at depths of more than 2700 meters.

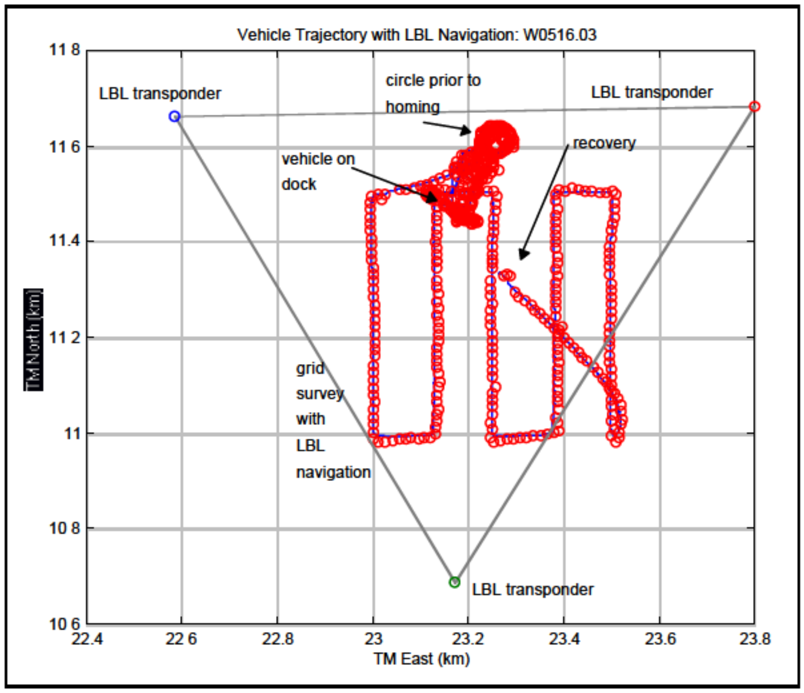
The introduction of the Utility Acoustic Modem (UAM) was a major milestone. This is an advanced modem designed for low power and small size to meet the requirements of small, high-performance AUVs. The first application of this DSP based system is as the processing engine for the ultrashort baseline (USBL) homing system required for docking the AUV.

RESULTS

Initial docking work addressed homing the vehicle to the dock, and a number of different homing schemes were tested. Acoustic homing systems were favored primarily for their large 'lock-on' distance. Ranges in excess of a kilometer have been achieved with the ultrashort baseline system employed for homing, even in shallow water, while the optical and electromagnetic systems required approaches closer than about 25 meters. Both the optical and electromagnetic systems appeared to provide more precise approaches, but, by designing capture mechanisms with wide apertures, this is less of a concern.

The dock and mooring systems pose significant technical challenges, especially for remote deep-water deployments. A significant result of 1997 was the integration of a dock onto a deep-water mooring, complete with satellite (INMARSAT) and direct radio-frequency communications. The successful deployment and recovery of the mooring and dock in 2700 m water increases our confidence in the viability of the overall system.

Vehicle-dock interaction becomes more complex as power and data transfer capabilities are integrated, and was the focus of much effort for the past year. For this generation system, the dock and vehicle must cooperatively accomplish the sequential steps of homing, capture, alignment of power/data transfer, battery charging, and data and command file transfer. Each step has a chance of failure. Consequently, a robust docking capability depends on recognizing failures and constructing new strategies to try again. Robust homing was clearly demonstrated during tests in which the dock was suspended from a swinging ship. The vehicle was forced to execute as many as four missed approaches before successfully docking in this dynamic environment.



Odyssey mission in which the vehicle is launched from the ship, circles until detecting homing beacon, docks, undocks and runs a grid survey pattern navigating with LBL. The vehicle is recovered to the surface, ending the mission.

Operations coupling the AUV surveys to measurements from other platforms, (e.g. moorings, drifters, ships, and other AUVs), have highlighted both the strength of spatially diverse sensing strategies and their relative difficulty. The strengths are compounded when complementary sensors are used for simultaneously characterizing the same region of water. For example, consider the use of an acoustic Doppler current profiler from an AUV high in the water column to image the same volume of water which is concurrently sampled by a profiling CTD vehicle. Difficulties stem from the complexity of developing survey plans which most effectively use multiple assets, and from the operational concerns of reliability and navigation. Operationally, the simplest strategies involve providing the vehicle with the ability to measure and maneuver relative to the other platform(s).

Efforts to integrate observations and models are accelerating. Acoustically Focused Ocean Sampling (AFOS) relies on the use of AUVs as moving sources to provide adaptive tomographic imaging of the ocean. Elements of this system were tested in the Haro Strait experiment, and analysis of the results clearly indicate that a rapid ocean-imaging system can be realized. However, a significant infrastructure, including acoustic communications, is required to support the system. The Harvard Oceanographic Prediction System (HOPS) was used to plan and assimilate AUV runs in Haro Strait. Success in coupling oceanographic models to AUV operations in this setting helped prime the Littoral Ocean Observation and Prediction System effort, now funded under the National Ocean Partnership Program.

IMPACT/APPLICATIONS

Individual components of the system, such as the AUVs and gliders, provide unique measurement capabilities for ongoing oceanographic field programs. The use of multiple vehicles allows synoptic surveys which would otherwise be prohibitively expensive. Perhaps most important, the work creates mobile platforms and supporting systems for extended deployment in remote (and not so remote) locations.

Many Navy missions, including mine countermeasures, surveillance, and tactical oceanography, will benefit from application of the developed technology.

TRANSITIONS

A demonstration cruise for NAVOCEANO began the transition of small, high performance AUVs to operational Navy assets. NAVOCEANO has created a center of excellence for AUV technology providing an entry point for ONR funded work.

Lockheed-Martin funded MIT to develop a vehicle for mine-countermeasures applications, CETUS, employing Odyssey design and construction techniques. This system was delivered to Lockheed and is being used for Navy funded research.

The Utility Acoustic Modem (UAM) is being made available to the research community through a modem pool established at WHOI under separate ONR funding.

While AOSN development presently focuses on oceanographic applications, the fundamental concepts apply to military missions including mine countermeasures and clandestine surveillance.

RELATED PROJECTS

This program is the lead element of the Multidisciplinary University Research Initiative collaboratively linked with the following ONR funded efforts:

1) The Ocean Frontal Dynamics experiment, under the ONR Vertically Integrated Research Initiative.
2) The Oceanic Deep Convection Accelerated Research Initiative.
3) The Littoral Ocean Observation and Prediction System (LOOPS), funded under the National Ocean Partnership Program.
4) Several STTR and SBIR efforts.
5) The "Extending Sensor Deployment through Integrated Energy Management" effort funded under the National Ocean Technology Program

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